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COMPUTER PROGRAMS FOR AUTOMATION OF TWO SMALL-ANGLE X-RAY SCATTERING DIFFRACTOMETERS

C. RICHARD DESPER
POLYMER & CHEMISTRY DIVISION

November 1976

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ARMY MATERIALS AND MECHANICS RESEARCH CENTER
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ABSTRACT

SPASTIC 76 is an update of previously reported programs written for a minicomputer to permit data acquisition with a small-angle X-ray diffractometer. SPASTIC denotes System for Programming Angles, Scaler, and Timer by Internal Counting, and indicates the general approach used for automation, involving a simple interface and stepping motor control. The present programs are written for two diffractometers of the Bonse-Hart and the Kratky designs, and run on a PDP-8L computer with 8,192 words of core memory. The various programs include routines for finding the zero position and integral breadth of the primary beam, and for step-scanning through the scattering regions. The latter routine incorporates integrations for the Porod invariant.

CONTENTS

INTRODUCTION

As described in an earlier report,[1] this laboratory has developed a computer-controlled X-ray diffraction instrument denoted as SPASTIC, an acronym for System for Programming Angles, Scaler, and Timer by Internal Counting. The system hardware is based on a PDP-8L computer interfaced to four stepping motors and an X-ray shutter, with an internal data-break scaler for counting X-ray photons, and a timer based on a crystal clock interrupt. The original system was used to control an Advanced Metals Research Model 6-220 Small Angle X-ray Scattering Diffractometer, using motor 1 for the 2θ and motor 2 for the attenuator wheel. Software was developed at the time of the previous report to perform simple control and data-taking operations, accessing the hardware through a modification of the FOCAL language interpreter, denoted SPASTIC 71.

The present report is an update prompted by several developments in the interim: (a) the addition of a Kratky-type small-angle X-ray scattering diffractometer and (b) expansion of the computer memory from 4,096 to 8,192 words, allowing for more complicated programming. The 2θ drive for the Kratky diffractometer has been assigned stepping motor number 3, while number 4 has been allocated to the Norelco wide-angle diffractometer. Software for the latter has not been implemented at this time, but extensive programs have been developed for the Advanced Metals Research (AMR) and Kratky diffractometers. At present, however, the system can control only one diffractometer at a time. The instrument to be used is selected by connecting cables from the computer interface to the appropriate shutter control and X-ray photon pulse jacks.

SPASTIC-76 INTERPRETER

Concurrent with the hardware changes, improvements have been made in the basic machine-language software, now called SPASTIC 76. The hardware functions have been given new names which more readily denote the operation each function performs, and which eliminate ambiguities in the earlier language (FADC, FEXP, FRAN) between SPASTIC control functions and conventional FOCAL functions. In addition, the LIBRARY command has been restored for flexible operation with the mass-storage disk, while the FSIN and FCOS functions have been dropped. The assembler language printout for the SPASTIC 76 interpreter is given in the Appendix.

The corresponding names for the SPASTIC functions in the 1971 and 1976 versions are summarized in Table 1. The actual operations performed by the six controlling functions, listed in detail in Table 2, have not changed in the interim, but the error codes (Table 3) have changed, since these depend upon the core address from which the error routine is called. One new error code has been added in SPASTIC 76: Code 19.72 indicates that one of the arguments of FSET exceeds 2^{23}, or 8,288,608. An undetected overflow of this type would result in erroneous scaler or timer readings in SPASTIC 71.

1. DESPER, C. R., and QUATIERI, T. F. *SPASTIC – A System for Programming Angles, Scalar, and Timer by Internal Counting.* Army Materials and Mechanics Research Center, AMMRC TR 72-17, June 1972.

Table 1. EQUIVALENT CONTROL FUNCTIONS IN SPASTIC 71 AND SPASTIC 76

SPASTIC 71	SPASTIC 76	Function
FADC	FDRV	Drive stepping motors
FDXS	FSET	Set timer limit, scaler limit, motor speed
FDIX	FOPR	Perform one of six possible operations
FEXP	FTIM	Run timer/scaler to limit value
FRAN	FSOL	Operate shutter solenoid
FAND	FAND	Logical AND

Table 2. SPASTIC 76 CONTROL FUNCTIONS

1. FDRV (A1, A2, A3, A4)

Initiate stepping motor drives. A1 through A4 are the number of steps for motors 1 through 4. Zero arguments are ignored and the argument list may be shortened.

2. FSET (TL, SL, MI)

Change timer and scaler limits and motor pulse interval. TL is the timer limit in clock units; SL is the scaler limit in counts; and MI is the motor pulse interval in clock units. Negative arguments are illegal. Zero arguments are ignored and the argument list may be shortened. Maximum value of any argument is 2^{23}, or 8,288,608.

The values in effect at load time are:

TL = 1,228,800 clock units (4096 sec)
SL = 1000 counts
MI = 1 clock unit (speed = 300 steps/sec)

3. FOPR (ARG)

Six options:

ARG = 0 Read scaler and timer into FOCAL variables S' and T' without stopping them.
ARG = 1 Stop scaler and timer, then read into S' and T'
ARG = 2 Reset and start scaler and timer.
ARG = 3 Return timer run status. FOPR is zero if the timer is running, positive if stopped, negative if a high count rate was detected. ARG = 0, 1, or 2 also returns timer run status.
ARG = 4 Return motor status, an integer 0 to 15. All motors stopped = 0; motor 1, 2, 3, or 4 running contributes 1, 2, 4, or 8 respectively.
ARG = 5 Stop all motors. Return motor status = 0.

4. FTIM (0)

Reset, start, and run scaler/timer to count or time limit. Count and time are read into S' and T', and the timer status is returned (see FOPR, ARG = 3).

5. FSOL (ARG)

ARG = 0 Close solenoid, disable scaler, and clear high count rate condition.
ARG = 1 Open solenoid, enable scaler, and enable clock for high count rate protection.
ARG = 2 Return solenoid status, 0 or 1.

6. FAND (N1, N2...)

Return the logical AND of integers N1 and N2. Not presently used, but will facilitate the independent control of several motors in conjunction with FOPR (4).

Table 3. SPASTIC 76 ERROR CODES

Code	Meaning
08.47	Too many function arguments, or unmatched parentheses
19.72	Argument of FSET exceeds 2^{23}
19.75	Argument of FSET is negative
19.:9	Attempt to change count or time limit with timer running
19.;3	Argument of FOPR outside range 0 to 5
20.03	Timer restart with high count rate uncleared

ZEROING PROGRAMS

One of the more convenient aspects of computer control for a small-angle X-ray scattering diffractometer is the ability to "zero" the instrument; i.e., to scan through the primary beam and find the true zero position in 2θ. Naturally, the beam must be considerably weakened to execute these programs, since the full power of the primary beam would damage the X-ray detector. This is accomplished by turning the attenuator wheel to the "3" position for the AMR instrument, and by inserting a special lead filter in the Kratky diffractometer. In the latter case, since the beam is not monochromatic, insertion of the filter changes the wavelength spectrum reaching the detector, selectively filtering out some of the characteristic radiation at 1.5418 angstroms while passing more of the white radiation in the 0.3 to 0.8 angstrom range. To avoid the electronic rejection of the latter, which often exceeds the characteristic radiation intensity under such circumstances, it is recommended that the radiation analyzer be set to integral mode to accept both types of radiation. The computer types out a reminder to this effect.

The zeroing programs for the AMR and Kratky diffractometers, written in the SPASTIC 76 variation of the FOCAL language, are given in Tables 4 and 5. Several improvements have been made on the SPASTIC 71 zeroing program: (a) the program prints out the entire intensity profile rather than the peak intensity only; (b) the zero determined is a true mathematical zero, defined as the center of gravity of the beam rather than the position of

Table 4. AMR ZEROING PROGRAM

```
*J
C-8K SPASTIC,76

10.10 E
10.15 T "AMR ZEROING, TH IN SECONDS"!;S U=FOPR(5);S ML=10;S DL=5
10.20 A "AT IS",U,"USE 3"!;S AC=3;S A2=800*(3-U)/6;D 16;D 16.1
10.40 S U=FSOL(1);A "THRESHOLD",TH;S MT=6E5/TH
10.50 S U=FSET(MT,1E3,1);D 19;I (TH-SI)12.40;S U=FSET(3E6,3E6)

12.20 S TL=TL+1;I (400-TL)13.90;S A1=50;D 16;D 20;I (SI-TH)12.20
12.40 T "FOUND"!!;S U=FSET(MT,1E4)

13.10 T "  SECONDS  CTS/SEC"!;S S1=0;S S2=0;S PS=PS+1
13.15 S TL=40*DL;S T0=-TL;S A1=T0;S HI=-1;D 16;F TC=T0,DL,TL;D 19
13.30 I (HI-20*SI)13.95;I (HI-20*S0)13.95;T !"CG FOUND"!;S HT=S1/S2
13.35 S A1=HT-TL-DL;D 16;T "POSITION",%6.01,HT/ML," NOW=0"!
13.50 S S2=(S2-(SI+S0)/2)*DL/ML;T "INTEGRAL BREADTH",S2/HI," SECONDS"!
13.65 T "MAX"%6,HC," CTS",HI," CTS/SEC"
13.75 S TC=FSOL(0);D 16.1;T !!"QUIT"!;Q
13.90 T !"NOT ";D 12.40;G 13.75
13.95 T !"HIGH TAIL"!;D 13.65;T !"AT ";D 13.35;I (PS-2)13.1
13.98 I (5-PS)13.75;S DL=2*DL;G 13.1

16.10 S U=FOPR(4);I (-U)16.1
16.20 I (-A1)16.3,16.3;S U=FDRV(A1-100)
16.25 S U=FOPR(4);I (-U)16.25;S A1=100
16.30 S U=FDRV(A1,A2);S A1=0;S A2=0

19.14 S U=FOPR(4);I (-U)19.14;S U=FTIM(0);I (U)19.9
19.16 S TI=T'/300;S SI=S'/TI;S S1=S1+TC*SI;S S2=S2+SI;I (-PS)19.18;R
19.18 T !%6.01,TC/ML,SI;I (TC-T0) 19.2,19.19,19.2
19.19 S S0=SI
19.20 I (SI-HI)19.3,19.3;S HI=SI;S HT=TC;S HC=S'
19.30 S U=FDRV(DL);R
19.90 S U=FSOL(0);T "XS CT RATE";Q

20.05 S U=FOPR(2)
20.10 S U=FOPR(4);I (-U)20.1
20.20 S U=FOPR(1);I (U)19.9;D 19.16
*
```

Table 5. KRATKY ZEROING PROGRAM

```
*J
C-8K SPASTIC,76

10.10 E
10.15 T !"KRATKY ZEROING, ANALYZER TO INTEGRAL"!!;S U=FOPR(5);S ML=8
10.20 T !"SLITS, MICRONS";A !"1",DL,"2",U;S DL=(DL+U)/2.5
10.40 S U=FSOL(1);A !"THRESHOLD",TH;S MT=6E5/TH
10.50 S U=FSET(MT,1E3,1);D 19;I (TH-SI)12.40;S U=FSET(3E6,3E6)

12.20 S TL=TL+1;I (100-TL)13.90;S A1=200;D 16;D 20;I (SI-TH)12.20
12.40 T "FOUND"!!;S U=FSET(MT,1E4)

13.10 T "  MICRONS  CTS/SEC"!;S S1=0;S S2=0;S PS=PS+1
13.15 S TL=40*DL;S T0=-TL;S A1=T0;S HI=-1;D 16;F TC=T0,DL,TL;D 19
13.30 I (HI-20*SI)13.95;I (HI-20*S0)13.95;T !"CG FOUND"!;S HT=S1/S2
13.35 S A1=HT-TL-DL;D 16;T "POSITION",%6.01,HT/ML," NOW=0"!
13.50 S S2=(S2-(SI+S0)/2)*DL/ML;T "INTEGRAL BREADTH",S2/HI," MICRONS"!
13.65 T "MAX"%6,HC," CTS",HI," CTS/SEC"
13.75 S TC=FSOL(0);D 16.1;T !!"QUIT"!;Q
13.90 T !"NOT ";D 12.40;G 13.75
13.95 T !"HIGH TAIL"!;D 13.65;T !"AT ";D 13.35;I (PS-3)13.1,13.75

16.10 S U=FOPR(4);I (-U)16.1
16.20 I (-A1)16.3,16.3;S U=FDRV(0,0,A1-100)
16.25 S U=FOPR(4);I (-U)16.25;S A1=100
16.30 S U=FDRV(0,0,A1);S A1=0

19.14 S U=FOPR(4);I (-U)19.14;S U=FTIM(0);I (U)19.9
19.16 S TI=T'/300;S SI=S'/TI;S S1=S1+TC*SI;S S2=S2+SI;I (-PS)19.18;R
19.18 T !%6.01,TC/ML,SI;I (TC-T0) 19.2,19.19,19.2
19.19 S S0=SI
19.20 I (SI-HI)19.3,19.3;S HI=SI;S HT=TC;S HC=S'
19.30 S U=FDRV(0,0,DL);R
19.90 S U=FSOL(0);T "XS CT RATE";Q

20.05 S U=FOPR(2)
20.10 S U=FOPR(4);I (-U)20.1
20.20 S U=FOPR(1);I (U)19.9;D 19.16
*
```

maximum intensity, and (c) the zeroing process is repeated if either end of intensity profile exceeds 5% of the maximum intensity, indicating that too much of the beam is outside the range of observation. As a by-product, the zeroing programs yield the integral breadth of the intensity profile. This is defined as the ratio of the integrated intensity to the maximum intensity; i.e., it is the width of a hypothetical rectangle whose height is the maximum intensity and whose area is equal to the integrated intensity.

Sample printouts from the execution of the two zeroing programs are given in Tables 6 and 7. For the AMR instrument (Table 6) the interval between data points in the profile determination is fixed at 0.5 second of arc. Since the AMR diffractometer has a fixed integral breadth of approximately 10 seconds when properly aligned, use of the 0.5-second interval should yield an acceptable center of gravity with negligible tails within two trials. If not, the interval is successively raised to 1, 2, and 4 seconds of arc before giving up the zeroing attempt. For the Kratky instrument (Table 7) the interval between data points is set to 1/20th of the sum of the input values of the entrance and receiving slit widths. Since the expected breadth of the primary beam is approximately the sum of the two slit widths, this interval gives a good measure of the beam profile.

STEP-SCAN PROGRAMS

The earlier report[1] included a simple step-scan program for use with the AMR diffractometer, capable of taking intensity measurements at a series of 2θ values with variable spacing along the 2θ axis. Our experience in using this program has resulted in a number of modifications which have improved the operation of the system. The modifications are as follows:

(A) Antibacklash--When 2θ is driven to a lower numerical value, the programs pass the final destination, then reverse the motor direction for setting the angle. Since the angle is therefore always set with the motor driving in the positive direction, the backlash is taken out of the drive train.

(B) Rezeroing--At the end of a step-scan execution, the shutter is closed and the 2θ angle is set to zero. Since stepping motor control does not give absolute feedback of the angle value, it is imperative to know the initial value of 2θ when starting a new program. This feature makes it easy to remember: if the last program terminated normally, 2θ was left as zero. For the AMR instrument, the attenuator is also left at #3 position, the correct value for 2θ equals zero.

(C) Angle Units--The present step-scan programs allow for different units for defining the 2θ angle. For the AMR diffractometer, two versions of the programs are maintained with 2θ defined in seconds and in minutes. For the Kratky diffractometer, the appropriate unit is microns of elevation of the receiving slit, since this variable is fixed by the motor drive. The corresponding angle depends upon the distance set between the 2θ pivot and the receiving slit. The distance commonly used in this laboratory is 229.2 mm, chosen so that $1°$ in 2θ corresponds to 4000 microns of elevation. Changing angle units is effected by defining a multiplier at the start of the program, which is the number of motor steps per unit of angle.

Table 6. EXECUTION OF AMR ZEROING PROGRAM

```
*GO
AMR ZEROING, TH IN SECONDS
AT IS:3 USE 3
THRESHOLD:1000 FOUND

   SECONDS  CTS/SEC        SECONDS  CTS/SEC        SECONDS  CTS/SEC

=-    20.0=     3.0     =-     6.0=   878.0     =      8.0=   335.0
=-    19.5=     6.0     =-     5.5=  1033.0     =      8.5=   273.0
=-    19.0=     6.0     =-     5.0=  1193.0     =      9.0=   190.0
=-    18.5=     6.0     =-     4.5=  1304.0     =      9.5=   126.0
=-    18.0=     8.0     =-     4.0=  1495.0     =     10.0=    88.0
=-    17.5=     4.0     =-     3.5=  1732.0     =     10.5=    58.0
=-    17.0=     9.0     =-     3.0=  1858.0     =     11.0=    27.0
=-    16.5=     7.0     =-     2.5=  2011.0     =     11.5=    16.0
=-    16.0=    13.0     =-     2.0=  2146.0     =     12.0=    12.0
=-    15.5=    12.0     =-     1.5=  2258.0     =     12.5=     8.0
=-    15.0=    12.0     =-     1.0=  2364.0     =     13.0=     3.0
=-    14.5=    12.0     =-     0.5=  2311.0     =     13.5=     5.0
=-    14.0=    18.0     =      0.0=  2290.0     =     14.0=     2.0
=-    13.5=    21.0     =      0.5=  2167.0     =     14.5=     3.0
=-    13.0=    22.0     =      1.0=  2111.0     =     15.0=     3.0
=-    12.5=    29.0     =      1.5=  2018.0     =     15.5=     2.0
=-    12.0=    35.0     =      2.0=  1869.0     =     16.0=     3.0
=-    11.5=    55.0     =      2.5=  1689.0     =     16.5=     1.0
=-    11.0=    82.0     =      3.0=  1546.0     =     17.0=     2.0
=-    10.5=   119.0     =      3.5=  1386.0     =     17.5=     2.0
=-    10.0=   132.0     =      4.0=  1277.0     =     18.0=     3.0
=-     9.5=   192.0     =      4.5=  1142.0     =     18.5=     0.0
=-     9.0=   258.0     =      5.0=   953.0     =     19.0=     0.0
=-     8.5=   309.0     =      5.5=   847.0     =     19.5=     2.0
=-     8.0=   384.0     =      6.0=   742.0     =     20.0=     1.0
=-     7.5=   474.0     =      6.5=   595.0     CG FOUND
=-     7.0=   616.0     =      7.0=   527.0     POSITION=-    0.4 NOW=0
=-     6.5=   774.0     =      7.5=   407.0     INTEGRAL BREADTH=     9.9 SECONDS
                                               MAX=   4728 CTS=   2364 CTS/SEC

                                               QUIT
                                               *
```

Table 7. EXECUTION OF KRATKY ZEROING PROGRAM

```
*GO

KRATKY ZEROING, ANALYZER TO INTEGRAL


SLITS, MICRONS
1:150 2:140
THRESHOLD:1000 FOUND

   MICRONS  CTS/SEC        MICRONS  CTS/SEC        MICRONS  CTS/SEC

=-   580.0=     7.0     =-   159.5=   964.0     =    261.0=   275.0
=-   565.5=    10.0     =-   145.0=  1063.0     =    275.5=   234.0
=-   551.0=     6.0     =-   130.5=  1227.0     =    290.0=   175.0
=-   536.5=     7.0     =-   116.0=  1304.0     =    304.5=   198.0
=-   522.0=     8.0     =-   101.5=  1332.0     =    319.0=   182.0
=-   507.5=     6.0     =-    87.0=  1426.0     =    333.5=   135.0
=-   493.0=     9.0     =-    72.5=  1467.0     =    348.0=   103.0
=-   478.5=    14.0     =-    58.0=  1540.0     =    362.5=    86.0
=-   464.0=     8.0     =-    43.5=  1520.0     =    377.0=    64.0
=-   449.5=    16.0     =-    29.0=  1[illegible]2.0     =    391.5=    54.0
=-   435.0=    16.0     =-    14.5=  1581.0     =    406.0=    29.0
=-   420.5=    26.0     =      0.0=  1562.0     =    420.5=    17.0
=-   406.0=    27.0     =     14.5=  1555.0     =    435.0=    18.0
=-   391.5=    50.0     =     29.0=  1463.0     =    449.5=     5.0
=-   377.0=    45.0     =     43.5=  1432.0     =    464.0=     6.0
=-   362.5=    59.0     =     58.0=  1308.0     =    478.5=     3.0
=-   348.0=    62.0     =     72.5=  1202.0     =    493.0=     6.0
=-   333.5=    83.0     =     87.0=  1135.0     =    507.5=     4.0
=-   319.0=   104.0     =    101.5=  1009.0     =    522.0=     5.0
=-   304.5=   141.0     =    116.0=   943.0     =    536.5=     2.0
=-   290.0=   163.0     =    130.5=   754.0     =    551.0=     4.0
=-   275.5=   221.0     =    145.0=   668.0     =    565.5=     3.0
=-   261.0=   306.0     =    159.5=   542.0     =    580.0=     6.0
=-   246.5=   373.0     =    174.0=   473.0     CG FOUND
=-   232.0=   438.0     =    188.5=   431.0     POSITION=-   14.6 NOW=0
=-   217.5=   525.0     =    203.0=   397.0     INTEGRAL BREADTH=   343.8 MICRONS
=-   203.0=   689.0     =    217.5=   374.0     MAX=   3164 CTS=   1582 CTS/SEC
=-   188.5=   772.0     =    232.0=   306.0
=-   174.0=   888.0     =    246.5=   267.0     QUIT
                                               *
```

(D) Attenuator Programming--For the AMR diffractometer, changes in the attenuator position have been incorporated into the step-scan programs.

(E) Multiple Scanning--One program has been written for repeated multiple scans using the Kratky camera, to average out possible fluctuations in primary beam intensity with time. Improved control over the cooling water flow rate in the X-ray tube has obviated the need for this program, but it is included for completeness.

(F) Integration for the Porod Invariant--Some minor additions to the programs have made it possible to calculate the Porod invariant $\tilde{Q}_m$ as a by-product of the step-scan program. The expression used[2] to calculate $\tilde{Q}_m$ is that suitable for use with experimental (smeared) intensity $\tilde{I}(m)$ obtained with long slits:

$$\tilde{Q}_m = \int_0^{\infty} m\, \tilde{I}(m)\, dm \tag{1}$$

where m is the elevation variable in microns as defined in the Kratky instrument. The value of $\tilde{Q}_m$ calculated by the program is, of course, an approximation based on the use of the trapezoid rule and a finite range of integration. Where a background determination is made, the appropriate value of $\tilde{Q}_m$ is the difference in the two integrals. In the case of the AMR diffractometer, the angle units are different, but the units of the invariant are printed out along with its numerical value in each case. Also, it is appropriate to point out that there is little experience with the present programs, and that asymptotic forms of the intensity curve are often used in the high and low end of the intensity curve to improve accuracy.

The step-scan programs for the AMR diffractometer are listed in Tables 8 and 9 for 2θ defined in terms of seconds or minutes of arc. The step-scan program for the Kratky diffractometer is listed in Table 10, while the multiple step-scan program for this instrument appears in Table 11.

For comparison, step-scans were run on the same sample on both the AMR and Kratky diffractometers. The sample chosen was a polypropylene fiber in the form of a mat of parallel yarns of such a thickness as to attenuate the AMR primary beam by a factor 0.513. The data obtained using the two instruments are given in Tables 12 and 13. The printout is somewhat self-explanatory, keeping in mind that input data always follows a colon, while output data follows an equal sign. The abbreviations used in the printout are: AT, attenuator setting; CT LMT, count limit; CTS, counts; DL, interval in 2θ; TH, 2θ; and TM LMT, time limit. In each case data is taken closely spaced at the lower 2θ values and more widely spaced at the higher values. The diffraction maximum occurs in both sets of data at $2\theta = 0.6°$ (36 minutes and 2400 microns for the two instruments) corresponding to a Bragg spacing of approximately 150 angstroms. The intensity at the diffraction maximum is higher by a factor of 33 for the Kratky diffractometer, which is in agreement with the ratio of 31 for the integral breadths of the primary beams of

2. ALEXANDER, L. E. *X-Ray Diffraction Methods in Polymer Science.* Wiley-Interscience, New York, 1969, p. 292.

Table 8. AMR STEP-SCAN PROGRAM, ANGLE IN SECONDS

```
*W
C-8K SPASTIC,76

02.04 S U=FSOL(0);T !!,"/SS, TH IN SECONDS",!;S ML=10
02.06 A "TH IS",TC,"AT IS",AC,!
02.10 A "CT LMT",MC,"TM LMT",MS,!
02.11 S MT=MS*300
02.20 S U=FSET(MT,MC,1);S I=0
02.30 TYPE "DATA PTS"
02.54 S I=I+1
02.56 A !"TH",TH(I),"AT",AT(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.09,2.54

03.09 S AT(I)=3;S A1=(TH(1)-TC)*ML;S I=0;S QM=0;S TL=TH(1);S AL=AT(1)
03.18 D 2.54;S TC=TH(I);I (DL(I))3.25,3.50
03.25 D 6;D 5;S TC=TC+DL(I);S U=FSGN(DL(I))
03.27 S U=U*(TH(I+1)-TC-U*1E-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(I))*ML;S TC=TH(I+1);D 6;D 5;G 3.18
03.45 S A1=DL(I)*ML;G 3.25
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;D 5.1;T " END",!!!;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(600)+FOPR(2)+FSOL(1)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT);S U=FTIM(0);I (U)5.50;I (FABS(AC-AL))5.2,5.2
05.10 T !"QM"%,QM," SEC SQD C/S, FOR AT"%2,AL,!;S QM=0;S TL=TC
05.20 T %6.01,#,!,"TH",TC,%1," AT",AC,%6," CTS",S'
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(SI*TC+SL*TL)*(TC-TL)/2
05.40 T %6.04," IN",SI;S TL=TC;S SL=SI;S AL=AC;R
05.50 T !!,"XS CT RATE",!!;S U=FSOL(0);Q

06.05 S A2=800*(AT(I)-AC)/6;S AC=AT(I)
06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FDRV(A1-100,A2);S A2=0;S A1=100;G 6.10
06.30 S U=FDRV(A1,A2);S A1=0;S A2=0
*
```

Table 9. AMR STEP-SCAN PROGRAM, ANGLE IN MINUTES

```
*W
C-8K SPASTIC,76

02.04 S U=FSOL(0);T !!,"/SS, TH IN MINUTES",!;S ML=600
02.06 A "TH IS",TC,"AT IS",AC,!
02.10 A "CT LMT",MC,"TM LMT",MS,!
02.11 S MT=MS*300
02.20 S U=FSET(MT,MC,1);S I=0
02.30 TYPE "DATA PTS"
02.54 S I=I+1
02.56 A !"TH",TH(I),"AT",AT(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.09,2.54

03.09 S AT(I)=3;S A1=(TH(1)-TC)*ML;S I=0;S QM=0;S TL=TH(1);S AL=AT(1)
03.18 D 2.54;S TC=TH(I);I (DL(I))3.25,3.50
03.25 D 6;D 5;S TC=TC+DL(I);S U=FSGN(DL(I))
03.27 S U=U*(TH(I+1)-TC-U*1E-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(I))*ML;S TC=TH(I+1);D 6;D 5;G 3.18
03.45 S A1=DL(I)*ML;G 3.25
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;D 5.1;T " END",!!!;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(600)+FOPR(2)+FSOL(1)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT);S U=FTIM(0);I (U)5.50;I (FABS(AC-AL))5.2,5.2
05.10 T !"QM"%,QM," MIN SQD C/S, FOR AT"%2,AL,!;S QM=0;S TL=TC
05.20 T %6.03,#,!,"TH",TC,%1," AT",AC,%6," CTS",S'
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(SI*TC+SL*TL)*(TC-TL)/2
05.40 T %6.04," IN",SI;S TL=TC;S SL=SI;S AL=AC;R
05.50 T !!,"XS CT RATE",!!;S U=FSOL(0);Q

06.05 S A2=800*(AT(I)-AC)/6;S AC=AT(I)
06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FDRV(A1-100,A2);S A2=0;S A1=100;G 6.10
06.30 S U=FDRV(A1,A2);S A1=0;S A2=0
*
```

Table 10. KRATKY STEP-SCAN PROGRAM, ANGLE IN MICRONS

```
*W
C-8K SPASTIC,76

02.04 S U=FSOL(0);T !!,"/SS, TH IN MICRONS",!;S ML=8
02.06 A "PRESENT TH",TC,!
02.20 S U=FSET(0,0,1)+FOPR(1);S I=0;T "DATA PTS"
02.54 S I=I+1
02.56 A !"TH",TH(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.09,2.54

03.09 S A1=(TH(1)-TC[illegible] I=0;S QM=0;S TL=TH(1);D 6
03.10 I (-FOPR(4)) [illegible]
03.11 T !,"SET ANALYZER TO DIFFERENTIAL"!
03.12 T "USE NICKEL FILTER",!!!;S U=FSOL(1)
03.13 A "CT LMT",MC,"TM LMT",MS,!;S MT=MS*300
03.14 I (FOPR(3))5.50;S U=FSET(MT,MC)
03.18 D 2.54;S TC=TH(I);C....NO ATTENUATOR WHEEL
03.20 D 6;D 5;I (DL(I))3.25,3.50
03.25 S TC=TC+DL(I);S U=FSGN(DL(I))
03.27 S U=U*(TH(I+1)-TC-U*1E-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(I))*ML;G 3.18
03.45 S A1=DL(I)*ML;G 3.20
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;T " QM"%,QM," M SQD C/S"!!;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(1500)+FSOL(1)+FOPR(2)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT);S U=FTIM(0);I (U)5.50
05.20 T %6,#,!,"TH",TC," CTS",S'
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(SI*TC+SL*TL)*(TC-TL)/2
05.40 T %6.02," IN",SI;S TL=TC;S SL=SI;R
05.50 T !!,"XS CT RATE",!!;S U=FSOL(0);Q

06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FSOL(0)+FDRV(0,0,A1-200)
06.25 S U=FOPR(4);I (-U)6.25;S A1=200
06.30 S U=FDRV(0,0,A1);S A1=0
*
```

Table 11. KRATKY MULTIPLE STEP-SCAN PROGRAM, ANGLE IN MICRONS

```
*W
C-8K SPASTIC,76

02.04 S QT=FSOL(0);T !!,"/MS, TH IN MICRONS",!;S ML=8
02.06 A "PRESENT TH",TC,!
02.10 A "NBR OF MULTIPLE SCANS",CY,!;S KC=0
02.20 S U=FSET(0,0,1)+FOPR(1);S I=0
02.54 S I=I+1;T %2,!,"GRP",I
02.56 A " TH",TH(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.06,2.54

03.05 T " QM"%,QM," M SQD C/S"!;S QT=QT+QM
03.06 S KC=KC+1;IF (CY-KC)3.50
03.09 S A1=(TH(1)-TC)*ML;S I=0;S QM=0;S TC=TH(1);S TL=TC;D 6
03.10 I (-FOPR(4))3.10;I (1-KC)3.18
03.11 T !,"SET ANALYZER TO DIFFERENTIAL",!,"USE NICKEL FILTER",!!!
03.12 A "CT LMT",MC,"TM LMT",MS,!;S MT=MS*300
03.14 S U=FSOL(1);T "SAMPLE I.D.";I (FOPR(3))5.50;A U
03.18 S I=I+1;S TC=TH(I)
03.20 D 6;D 5;I (DL(I))3.25,3.05
03.25 S TC=TC+DL(I);S U=FSGN(DL(I))
03.27 S U=U*(TH(I+1)-TC-U*1E-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(I))*ML;G 3.18
03.45 S A1=DL(I)*ML;G 3.20
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;T !"AVERAGE ";S QM=QT/CY;D 3.05;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(1500)+FSOL(1)+FOPR(2)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT,MC);S U=FTIM(0);I (U)5.50
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(QI*TC+SL*TL)*(TC-TL)/2
05.40 T %6,#!,TC,S',%6.03,SI;S TL=TC;S SL=SI;R
05.50 T !!,"XS CT RATE",!!;S U=FSOL(0);Q

06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FSOL(0)+FDRV(0,0,A1-200)
06.25 S U=FOPR(4);I (-U)6.25;S A1=200
06.30 S U=FDRV(0,0,A1);S A1=0
*
```

Table 12. EXECUTION OF AMR STEP-SCAN PROGRAM

```
*GO


/SS, TH IN MINUTES
TH IS:0 AT IS:3
CT LMT:1E3 TM LMT:1200
DATA PTS
TH:5 AT:0 DL:1
TH:15 AT:0 DL:3
TH:60 AT:0 DL:0
TH=    5.000 AT= 0 CTS=    1000 IN=   3.4468
TH=    6.000 AT= 0 CTS=    1000 IN=   2.4962
TH=    7.000 AT= 0 CTS=    1000 IN=   1.8854
TH=    8.000 AT= 0 CTS=    1000 IN=   1.5868
TH=    9.000 AT= 0 CTS=    1000 IN=   1.3465
TH=   10.000 AT= 0 CTS=    1000 IN=   1.1234
TH=   11.000 AT= 0 CTS=    1000 IN=   1.0215
TH=   12.000 AT= 0 CTS=    1000 IN=   0.9734
TH=   13.000 AT= 0 CTS=     984 IN=   0.8200
TH=   14.000 AT= 0 CTS=     940 IN=   0.7833
TH=   15.000 AT= 0 CTS=     892 IN=   0.7433
TH=   15.000 AT= 0 CTS=     904 IN=   0.7533
TH=   18.000 AT= 0 CTS=     814 IN=   0.6783
TH=   21.000 AT= 0 CTS=     868 IN=   0.7233
TH=   24.000 AT= 0 CTS=     802 IN=   0.6683
TH=   27.000 AT= 0 CTS=     890 IN=   0.7417
TH=   30.000 AT= 0 CTS=    1000 IN=   0.8910
TH=   33.000 AT= 0 CTS=    1000 IN=   1.0449
TH=   36.000 AT= 0 CTS=    1000 IN=   1.4039
TH=   39.000 AT= 0 CTS=    1000 IN=   1.2669
TH=   42.000 AT= 0 CTS=    1000 IN=   0.9537
TH=   45.000 AT= 0 CTS=     712 IN=   0.5933
TH=   48.000 AT= 0 CTS=     528 IN=   0.4400
TH=   51.000 AT= 0 CTS=     426 IN=   0.3550
TH=   54.000 AT= 0 CTS=     338 IN=   0.2817
TH=   57.000 AT= 0 CTS=     322 IN=   0.2683
TH=   60.000 AT= 0 CTS=     288 IN=   0.2400
QM= 0.124484E+04 MIN SQD C/S, FOR AT=  0
 END
```

Table 13. EXECUTION OF KRATKY STEP-SCAN PROGRAM

```
 GO


/SS, TH IN MICRONS
PRESENT TH:0
DATA PTS
TH:500 DL:100
TH:1000 DL:200
TH:4000 DL:0
SET ANALYZER TO DIFFERENTIAL
USE NICKEL FILTER


CT LMT:1E3 TM LMT:100

TH=     500 CTS=    1000 IN=  103.59
TH=     600 CTS=    1000 IN=   63.87
TH=     700 CTS=    1000 IN=   54.43
TH=     800 CTS=    1000 IN=   53.19
TH=     900 CTS=    1000 IN=   49.59
TH=    1000 CTS=    1000 IN=   43.59
TH=    1200 CTS=    1000 IN=   37.30
TH=    1400 CTS=    1000 IN=   34.86
TH=    1600 CTS=    1000 IN=   31.43
TH=    1800 CTS=    1000 IN=   32.25
TH=    2000 CTS=    1000 IN=   36.68
TH=    2200 CTS=    1000 IN=   41.64
TH=    2400 CTS=    1000 IN=   47.02
TH=    2600 CTS=    1000 IN=   43.65
TH=    2800 CTS=    1000 IN=   33.76
TH=    3000 CTS=    1000 IN=   24.35
TH=    3200 CTS=    1000 IN=   20.89
TH=    3400 CTS=    1000 IN=   17.93
TH=    3600 CTS=    1000 IN=   16.50
TH=    3800 CTS=    1000 IN=   16.07
TH=    4000 CTS=    1000 IN=   14.84
QM= 0.233214E+09 M SQD C/S
*
```

the two instruments as given in Tables 6 and 7. The lower resolution of the Kratky instrument using the present slit settings allows for much higher levels of diffracted beam intensity. The price that one pays for this intensity is in terms of the minimum angle at which one can take useful data, which is 500 microns, or 0.125°, for the Kratky diffractometer. The data on the AMR instrument starts at 5 minutes, or 0.083°, and could well start much lower. In all fairness, however, it must be stated that the Kratky diffractometer is capable of the same resolution at the AMR instrument if finer slits and a longer working distance are used. The present coarse resolution conditions are deliberately chosen to enhance intensity at the expense of resolution.

As a final demonstration, the multiple step-scan program was executed. A step-scan similar to that of Table 13 was executed ten times. Since the entire intensity data generated is rather voluminous, only a summary is given in Table 14, in the form of the Porod invariant for the ten scans. Any long-term drift in the primary beam intensity would appear as a corresponding change in $\mathcal{Q}_m$. Although a small drift may be indicated by the systematic changes in $\mathcal{Q}_m$ over the ten scans, the effect appears only in the third digit and leads to less than 1% error in $\mathcal{Q}_m$. A greater source of error lies in the fact that the integral for the Porod invariant (Eq. 1) has been truncated to cover something less than the full range zero to infinity.

Table 14. RESULTS OF KRATKY MULTIPLE STEP-SCAN EXECUTION

Scan No.	Porod Invariant
1	0.111372 E + 09
2	0.112771 E + 09
3	0.112852 E + 09
4	0.113289 E + 09
5	0.113972 E + 09
6	0.114016 E + 09
7	0.115220 E + 09
8	0.114224 E + 09
9	0.113563 E + 09
10	0.113561 E + 09
Average	0.113584 E + 09 ± 0.90%

APPENDIX. PALD ASSEMBLY OF SPASTIC 76

```
/       S.P.A.S.T.I.C. - TAPE 1 - 19 FEB 1976
/FSIN AND FCOS DROPPED, LIBRARY COMMAND ALLOWED
/
/SYSTEM FOR PROGRAMMING ANGLES,SCALAR,AND TIMER
/BY INTERNAL COUNTING
/OVERLAY FOR FOCAL, 1969 FOR XRAY SCATTERING EXPERIMENTS
/RICHARD DESPER, AMMRC, WATERTOWN, MASS.
/COMPATIBLE WITH FOCAL 69
/       ...DO NOT USE INIT...
/4 WORD OVERLAY CAN BE USED, LOAD B4 SPASTIC
/8K OVERLAY SHOULD BE USEABLE, LOAD B4 SPASTIC
/
/FOCAL FLOATING POINT OPERATORS
/
/       ...CAUTION...
/SOME OF THESE DIFFER FROM STANDARD
/FLOATING POINT OPERATORS
/
/       ......NOTE...... PALD DOES NOT RECOGNIZE FIXMRI
/       USE PAL III INSTEAD OR DELETE FIXMRI, SINCE
/       FIXTAB WILL TAKE CARE OF IT IN PALD
/
FGET=0000
FADD=1000
FSUB=2000
FDIV=3000
FMUL=4000
FPOW=5000
FPUT=6000
/THE ABOVE 7 SYMBOLS REQUIRE FIXMRI FOR PAL III
FNOR=7000
FEXT=0000
/
/HARDWARE IOT'S
/
SNCF=6311/SKIP IF NO CLOCK FLAG
CCF=6312/CLEAR CLOCK FLAG,ENABLE CLOCK
DSCK=6314/DISABLE CLOCK
DSCF=6316/CLEAR CLOCK FLAG AND DISABLE
ENSL=6351/ENABLE SOLENOID AND SCALAR
DSSL=6352/DISABLE SOLENOID AND SCALAR
/STEPPING MOTOR NE-STEP IOTS-
M1F=6321/MOTOR 1 FORWARD
M2F=6331/MOTOR 2 FORWARD
M3F=6334/MOTOR 3 FORWARD
M4F=6341/MOTOR 4 FORWARD
M1R=6322/MOTOR 1 REVERSE
M2R=6324/MOTOR 2 REVERSE
M3R=6332/MOTOR 3 REVERSE
M4R=6342/MOTOR 4 REVERSE
/
/FOCAL SUBROUTINE CALLS
/
FENT=JMS I 7/FLT PT INTRPTR
POPA=TAD I 13/RESTORE AC
NEGATE=JMS I 51/NEGATE FLAC
INTEGR=JMS I 53/FIX FLAC
RETURN=JMP I 136/FUNCTION RETURN
PUSHJ=JMS I 140/RECURSIVE SUBRTN CALL
POPJ=JMP I 141/SUBRTN RETURN
PUSHA=JMS I 142/SAVE AC
```

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SPASTIC 76 is an update of previously reported programs written for a minicomputer to permit data acquisition with a small-angle X-ray diffractometer. SPASTIC denotes System for Programming Angles, Scaler, and Timer by Internal Counting, and indicates the general approach used for automation, involving a simple interface and stepping motor control. The present programs are written for two diffractometers of the Bonse-Hart and the Kratky designs, and run on a PDP-8L computer with 8,192 words of core memory. The various programs include routines for finding the zero position and integral breadth of the primary beam, and for step-scanning through the scattering regions. The latter routine incorporates integrations for the Porod invariant.

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Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
COMPUTER PROGRAMS FOR AUTOMATION OF TWO
SMALL-ANGLE X-RAY SCATTERING DIFFRACTOMETERS –
C. Richard Desper

AD ________________

UNCLASSIFIED
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```
                PUSHF=JMS I 143/AVE FLT PT NBR
                POPF=JMS I 144/RESTORE FLT PT NBR
                PRINTC=JMS I 151/PRINT CHAR
                ERROR=JMS I 166/ERROR RECOVERY
                FIXTAB
                /
                /MEMORY FIELD CONTROL IOTS
                CDF=6201
                CIF=6202
                /
                /FOCAL STORAGE LOCNS
                /
                PT1=30
                EX1=40
                FLAC=44
                ADD=61
                CHAR=66
                P7700=101
                P7600=104
                C260=113
                M5=120
                START=177
                FNTABF=374
                ILGL=634
                GS1=1437
                EVAL=1613
                FNTABL=2165
                SAVLK=2601
                ERROR5=2725
                RECOVR=2740
                DIV2=6757
                PRNTR=7527
                DLIB=7557
                LINE0=100 /FIELD 1
                DLIB8=120 /FIELD 1
                RLIB= 125 /FIELD 1
                /
                /
                /
                /      S.P.A.S.T.I.C. - TAPE 2
                /PAGE ZERO PATCH-FOCAL 69
                /
                /START OF INTERRUPT SVC MODIFIED
                /NOT INTENDED FOR PDP-5 OR PDP-8S
                /
                FIELD 0/SET FIELD ZERO INDICATOR
                *1
0001    5402    JMP I .+1
0002    6172    INTRPX /ADS MODFD
0003    0000    SAVACX,0
                /
                /CHANGE BOTTOM
                *35
0035    4673    BUFEND-2
                /
                /MODIFY INITIALIZN ADS
                *176
0176    4365    BEGINX
                /
                /MODIFY FUNCTION ADDRESS TABLE
                *FNTABF+3
0377    4757    FOPR
```

```
0400  5023  FSOL
0401  5200  FDRV
0402  4717  FSET
0403  5105  FTIM
0404  1142  FAND
            /PUT ERRORS IN NEXT TWO LOCNS SINCE SIN, COS ARE DROPPED
0405  2725  ERRORS
0406  2725  ERRORS
            /
            /AND FUNCTION - CALLED BY FAND(I1,I2...)
            /THIS FUNCTION IS REENTRANT, ARGUMENT LIST UNLIMITED
            /ARGS ASSUMED IN RANGE 0-4095, NO CHECK MADE
            *1142
1142  4453  FAND,INTEGR
1143  4542  PUSHA
1144  4540  PUSHJ
1145  1343  ARG
1146  5354  JMP .+6
1147  4453  INTEGR
1150  7200  CLA
1151  1413  POPA
1152  0046  AND FLAC+2
1153  5343  JMP FAND+1
1154  1413  POPA / EXIT
1155  3046  DCA FLAC+2
1156  5536  RETURN
            /
            /RETAIN LIBRARY COMMAND AT LOCN 1173 (2-74)
            /
            /ARGUMENT EVALUATOR
            /
            *1343
1343  1066  ARG,TAD CHAR
1344  1353  TAD MCOMMA
1345  7640  SZA CLA/LAST CHAR=,?
1346  5352  JMP .+4
1347  4540  PUSHJ    /YES-GET ANOTHER ARG
1350  1612  EVAL-1
1351  7001  IAC      /AND SKIP INSTR ON RETURN
1352  5541  POPJ     /OTHERWISE NO SKIP
1353  7524  MCOMMA,-254
            /
            *1553
1553  6321  IOTBL,M1F / LIST OF STEPPING MOTOR IOTS
1554  6322  M1R
1555  6331  M2F
1556  6324  M2R
1557  6334  M3F
1560  6332  M3R
1561  6341  M4F
1562  6342  M4R
            /
            /CHANGE FUNCTION NAMES - SEE FOCAL EFUN FOR CODING
            /CODE FOR FXYZ IS 4X+2Y+Z,
            /CODE FOR FYZ IS 2Y+Z,
            /CODE FOR FZ IS Z
            /WHERE X,Y,Z ARE ASCII VALUES
            *FNTABL+3
2170  2656  2656 /FOPR
2171  2666  2666 /FSOL
2172  2612  2612 /FDRV
2173  2652  2652 /FSET
```

```
2174  2657  2657 /FTIM
2175  2544  2544 /FAND
            /
            /CHANGES IN INTERRUPT SERVICE PAGE
            *2600
2600  0000  BREAK,0/OLD SAVAC - RESERVE FOR HARDWARE SCALAR
            /
            *2603
2603  3201  INTRPT,DCA SAVLK/REACHED VIA INTRPX
2604  6311  SNCF
2605  5654  JMP I LCKSVC/SERVICE CLOCK
2606  6041  BACK,TSF
            /
            *2640
2640  5576  JMP I START-1/PROVIDED CNTRL-C WITH NEW RECOVER
            *2653
2653  7410  SKP/DELETE PDP-8S PARITY CHECK
2654  5270  LCKSVC,CKSVC
            /
            *2657
2657  1003  TAD SAVACX/RESTORE AC FROM NEW LOCN
            /
            /
            /
            /       S.P.A.S.T.I.C. - TAPE 3
            /CHANGE WRITE INSTRUCTION HEADING (4K)
            *3211
3211  2320  2320 /SP
3212  0123  0123 /AS
3213  2411  2411 /TI
3214  0354  0354 /C,
3215  6766  6766 /76
            /BIN PUNCH RTN - SAME AS DEC-08-YXYA-PB
            /WITH START ADS CHANGED TO 3465
            /
            /DROPPED IN THIS VERSION - CANT PUNCH FIELD 1
            /
            /
            /
            /       S.P.A.S.T.I.C. - TAPE 4
            /MODIFY STARTING PROCEDURE TO GIVE INITIAL IOTS TO
            /SOLENOID AND CLOCK
            *4365
4365  6352  BEGINX,DSSL /DISABLE SOLENOID AND SCALAR
4366  6316  DSCF /DISABLE CLOCK ANDCLEAR FLAG
4367  7410  SKP
4370  4773  NURCVR
            /
            /CERTAIN LAB-8 IOTS IN INITIAL RTN INTERFERE
            /WITH STEPPING MOTOR IOTS M2F AND M4R (6331,6342)
            /IF YOU USE A LAB-8 SYSTEM THESE STEPPING MOTOR IOT
            /MUST BE CHANGED IN THE HARDWARE
            /ERASE OFFENDING LAB-8 IOTS -
            *4400
4400  7000  NOP
            *4436
4436  7000  NOP
            /PDP-5 AND PDP-8S ARE FORBIDDEN
            /PROBLEM IS SPACE LIMITATIONS
            /IN PAGE 000 AND PAGE 2600
            /
            /
```

```
                /HALT ON INITIAL DIALOGUE,PDP-8S
                /NO ROOM ON PAGE 2600 FOR
                /MEMORY PARITY CHECK
                /PDP-8S IS PROBABLY TOO SLOW ANYWAY
                *4456
4456  7402      HLT
                /
                /HALT ON INITIAL DIALOGUE, PDP-5
                /NO ROOM FOR USE OF LOCN
                /0002 AS JMP INSTRUCTION
                *4463
4463  7402      HLT
                /
                /THESE COMPUTERS COULD BE USED
                /IF THE 8K OPTION IS DROPPED
                /BY MAKING USE OF LOCNS
                /0167-0175 ON PAGE 0000
                /
                *4523
4523  7200      CLA /PATCH OUT INIT
                /SET BUFFER LIMIT ON INITIALIZN
                *4557
4557  4673      BUFEND-2
                /
                /
                /
                /        S.P.A.S.T.I.C. - TAPE 5
                /FSET ROUTINE - SETS TIME AND COUNT LIMITS
                /ARGUMENTS=(TL,SL,MI)
                /TL=PRESET TIME LIMIT,CLOCK UNITS
                /SL=PRESET COUNT LIMIT
                /MI=MOTOR PULSE INTERVAL,CLOCK UNITS
                /ZERO ARGS ARE IGNORED
                /NEG ARGS=ERROR
                /CLOCK UNIT=1-300TH SEC
                /
                *4675
                BUFEND=.
4675  4540      ARGINT,PUSHJ / GET ANOTHER ARGUMENT
4676  1343      ARG
4677  5541      POPJ / NO ARG, RETURN WITHOUT SKIP
4700  4453      INTSGN,INTEGR / ENTRY FOR FIRST ARG
4701  7450      SNA
4702  1045      TAD FLAC+1
4703  7650      SNA CLA
4704  5541      POPJ / ARG=0, RETURN WITHOUT SKIP
4705  1044      TAD FLAC
4706  1346      TAD M27
4707  7640      SZA CLA
4710  4566      ERROR /ARG EXCEEDS 2 TO 23RD (APPROX 8E6)
4711  1045      TAD FLAC+1
4712  7710      SPA CLA
4713  4566      ERROR / ARG=-, ERROR MSG
4714  4451      NEGATE / ARG +, MAKE IT -
4715  7001      IAC
4716  5541      POPJ / SKIP INSTR ON RETURN
                /
4717  4540      FSET,PUSHJ / FSET STARTS HERE
4720  4700      INTSGN
4721  5327      JMP SLIN / TL=0, IGNORE IT
4722  4352      JMS RNCH
```

```
4723  4543  PUSHF
4724  0044  FLAC
4725  4544  POPF
4726  6315  TIMELM / SET TIME LIMIT
4727  4540  SLIN,PUSHJ
4730  4675  ARGINT
4731  5340  JMP MIIN /        SL=0, IGNORE IT
4732  4750  JMS I LDIV2
4733  4352  JMS RNCH
4734  4543  PUSHF
4735  0044  FLAC
4736  4544  POPF
4737  6311  COUNTL
4740  4540  MIIN,PUSHJ
4741  4675  ARGINT
4742  5536  RETURN
4743  1046  TAD FLAC+2
4744  3747  DCA I LMSPD / MI IS SINGLE PREC
4745  5536  RETURN
            /
4746  7751  M27,-27
4747  5372  LMSPD,MSPEED
4750  6757  LDIV2,DIV2
4751  5370  LRN,RUN
4752  0000  RNCH,0 / CHECK TIMER RUN STATUS
4753  1751  TAD I LRN
4754  7650  SNA CLA
4755  4566  ERROR / MUST BE OFF WHEN CHANGING LIMITS
4756  5752  JMP I RNCH
            /
            /ENTRY TO FOPR FUNCTION
            /
            /FOPR(0) - READ SC, TM WITHOUT STOPPING THEM
            /FOPR(1) - STOP SC, TM, THEN READ THEM
            /FOPR(2) - RESET AND START SC, TM
            /FOPR(3) - RETURN TIMER STATUS,- FOR HI CT RATE,
            / 0 FOR TIMER RUNNING, + FOR TIMER STOPPED NORMALLY.
            /FOPR(4) - RETURN MOTOR STATUS - INTEGER 0 THRU 15
            / 0 FOR ALL MOTORS STOPPED
            / ADD 1 FOR MTR 1 RUNNING, 2 FOR MTR 2 RUNNING, 4 FOR MTR 3
            / RUNNING, 8 FOR MTR 4 RUNNING
            /FOPR(5) - STOP ALL MOTORS, RETURN FOPR=0
            / USE FOPR(5) TO INITIALIZE SPASTIC PROGRAMS IN CASE
            / SYSTEM HAD BEEN STOPPED WITH A MOTOR RUNNING
            / OTHERWISE THAT MOTOR WILL RESTART WHENEVER CCF IS EXECUTED
            /
4757  4453  FOPR,INTEGR
4760  7510  SPA
4761  4566  ERROR / NEGATIVE ARG
4762  1120  TAD M5
4763  7740  SMA SZA CLA
4764  5361  JMP .-3 / ARG EXCEEDS 5
4765  1371  TAD BRANCH
4766  4542  PUSHA / SAVE ADS
4767  1046  TAD FLAC+2
4770  5541  POPJ / BRANCH OUT
4771  5112  BRANCH,XFOPR
            /
4772  5033  SOLND
4773  7300  NURCVR,CLA CLL / RESPONSE TO CNTRL-C OR RESTART AT 200
4774  4772  JMS I .-2
4775  6314  DSCK
```

```
4776  5777  JMP I .+1
4777  2740  RECOVR / CHANGE TO 7600 TO JUMP TO DISC MONITOR
            /NOTE THAT SUCH A CHANGE AFFECTS RESTART AT 0200 AS WELL
            /AS CNTRL-C KEYBOARD SIGNAL
            /IN SUCH EVENT USE 2740 AS RESTART ADS AND
            /REMEMBER THAT HARDWARE MAY NOT BE INITIALIZED
            /
            /
            /
            /       S.P.A.S.T.I.C. - TAPE 6
            /RESET AND START SCALAR AND TIMER
            /THE ONE-BIT PRESCALAR B4 SCALAR DATA BREAKS
            /IS NOT RESET. ERROR=0,0,-1, OR +1 ON TOTAL COUN
            /THIS ERROR IS INSIGNIFICANT AND CANCELS OUT
            /OVER A NUMBER OF INTENSITY DETERMINATIONS.
            /
            *5000
5000  0000  RESTRT,0
5001  1704  TAD I LOCRUN
5002  7710  SPA CLA
5003  4566  ERROR   / RESTRT CANNOT BE CALLED AFTER HI CT RATE
5004  6002  IOF     / UNTIL RUN IS CLEARED BY FSOL(0)
5005  4543  PUSHF
5006  6311  LCOL,COUNTL
5007  4544  POPF
5010  5360  LCOUNT,COUNT
5011  4543  PUSHF
5012  6315  LTIL,TIMELM
5013  4544  POPF
5014  5364  LTIME,TIME
5015  3704  DCA I LOCRUN
5016  3622  DCA I LBREAK
5017  6312  CCF/ENABLE CLOCK AND SCALAR
5020  6001  ION
5021  5600  JMP I RESTRT
5022  2600  LBREAK,BREAK
            /
            /FSOL-OPEN,CLOSE,OR READ SOLENOID
            /ARG=0  CLOSE
            /ARG=1  OPEN IT
            /ARG=2  READ IT BUT DON'T CHANGE IT
            /IN ANY EVENT, SOLENOID VALUE IS RETURNED
5023  4453  FSOL,INTEGR
5024  7110  CLL RAR
5025  7640  SZA CLA
5026  5231  JMP .+3
5027  7004  RAL
5030  4233  JMS SOLND
5031  1247  TAD SOLVAL
5032  5323  JMP DCFL2
            /
            /SOLENOID POSITIONING ROUTINE
            /ENTER AC=0 OR 1 FOR CLOSED
            /OR OPEN SOLENOID
            /
5033  0000  SOLND,0
5034  7450  SNA
5035  5241  JMP .+4
5036  6351  ENSL / AC=1, OPEN SOLENOID
5037  6312  CCF / ALSO ENABLE CLOCK AS HI CT RATE PROTXN
5040  5244  JMP .+4
5041  6352  DSSL / AC=0, CLOSE SOLENOID
```

```
5042  7001  IAC
5043  3704  DCA I LOCRUN / CLEAR HI CT RATE FLAG
5044  3247  DCA SOLVAL / SAVE AC
5045  3622  DCA I LBREAK
5046  5633  JMP I SOLND
5047  0000  SOLVAL,0 / STORE FOR FSOL(2)
            /
            /       THE FLWG RTNS ARE ON THE SAME PAGE AS REST
            /       AND ARE MOVED IF RESTRT IS MOVED
            /
            /SCALAR AND TIMER READ OPERATIONS
            /SCALAR CONTENTS PLACED AT S', TIMER AT T'
            /
            /F1-STOP THEM FIRST
            /F1 DOES NOT CLEAR NEG RUN FLAG
5050  2704  F1,ISZ I LOCRUN
            /MERGE WITH F0,DYNAMIC READ
5051  1302  F0,TAD SCKODE
5052  3061  DCA ADD
5053  4540  PUSHJ
5054  1437  GS1
5055  6002  IOF/FREEZE COUNT+TIME
5056  4407  FENT
5057  0610  FGET I LCOUNT
5060  2606  FSUB I LCOL
5061  7000  FNOR
5062  6430  FPUT I PT1
5063  0000  FEXT
5064  1303  TAD TMKODE
5065  3061  DCA ADD
5066  4540  PUSHJ
5067  1437  GS1
5070  4407  FENT
5071  0614  FGET I LTIME
5072  2612  FSUB I LTIL
5073  7000  FNOR
5074  6430  FPUT I PT1
5075  0000  FEXT
5076  6001  ION
            /
            /MERGE WITH F3, TIMER STATUS CHECK
            /
5077  1704  F3,TAD I LOCRUN/SET FUNCTION SGN -,0,OR+
5100  3045  DCA FLAC+1/TO COINCIDE WITH SIGN OF RUN
5101  5323  JMP DCFL2
5102  2347  SCKODE,2347/ PACKED
5103  2447  TMKODE,2447/ ASCII
5104  5370  LOCRUN,RUN
            /
            /FTIM-RUN SCALAR AND TIMER
            /FOR PRESET COUNT OR TIME
            /INTERVAL,THEN READ
            /
            /       NOTE
            /
            /NEITHER FOPR(2) OR FTIM(...) OPENS THE SOLENOID
            /THIS MUST BE DONE SEPARATELY BY FSOL(1)
            /ALSO, THESE ROUTINES MAY BE USED WITH SOLENOID
            /CLOSED FOR TIME DELAY WITHOUT COUNTING
            /
5105  4200  FTIM,JMS RESTRT
5106  7120  CLL CML / DISPLAY LINK = 1 IN FTIM WAIT
```

```
5107  1704  TAD I LOCRUN
5110  7650  SNA CLA
5111  5307  JMP .-2/WAIT FOR PRESET
            /TABLE FOR FOPR
            /DO NOT CHANGE SEQUENCE OF LOCNS XFOPR-1 TO XFOPR+5
5112  5251  XFOPR,JMP F0
5113  5250  JMP F1
            /
            /F2, RESET AND START TIMER-SCALAR, RETURN STATUS
5114  4200  JMS RESTRT
5115  5277  JMP F3
5116  5325  JMP F4
            /F5 - STOP ALL MOTORS
5117  3347  F5,DCA STEP1
5120  3351  DCA STEP2
5121  3353  DCA STEP3
5122  3355  DCA STEP4
5123  3046  DCFL2,DCA FLAC+2
5124  5536  RETURN
            /CHECK MOTOR STATUS
            /FOPR(4) ROUTINE
5125  3046  F4,DCA FLAC+2
5126  1355  TAD STEP4
5127  4337  JMS MCHK
5130  1353  TAD STEP3
5131  4337  JMS MCHK
5132  1351  TAD STEP2
5133  4337  JMS MCHK
5134  1347  TAD STEP1
5135  4337  JMS MCHK
5136  5536  RETURN
5137  0000  MCHK,0 / CHECK 1 MOTOR, SAVE STATUS AT FLAC+2
5140  7100  CLL
5141  7640  SZA CLA
5142  7020  CML / SET LINK=1 IF RUNNING
5143  1046  TAD FLAC+2
5144  7004  RAL
5145  3046  DCA FLAC+2 / SAVE STATUS AT BIT 11
5146  5737  JMP I MCHK
            /
5147  0000  STEP1,0/MOTOR 1
5150  0000  0
5151  0000  STEP2,0/MOTOR 2
5152  0000  0
5153  0000  STEP3,0/MOTOR 3
5154  0000  0
5155  0000  STEP4,0/MOTOR 4
5156  0000  0
            /INCREMENT A DOUBLE PRECISION NUMBER
            /FOR USE ONLY BY CKSVC
5157  0000  DBLINC,0
5160  1757  TAD I DBLINC
5161  3374  DCA TDB1
5162  7101  CLL IAC
5163  1374  TAD TDB1
5164  3375  DCA TDB1+1
5165  2357  ISZ DBLINC
5166  2775  ISZ I TDB1+1
5167  5757  JMP I DBLINC
5170  2774  ISZ I TDB1 / INCRT HI BITS
5171  5757  JMP I DBLINC
5172  7020  CML / SET LINK IF HI BITS OVERFLOW
```

```
5173  5757  JMP I DBLINC
5174  0000  TDB1,0
5175  0000  0
            /
            /
            /
            /
            /       S.P.A.S.T.I.C. - TAPE 7
            /FDRV ROUTINE
            /INITIATES STEPPING MOTOR DRIVES
            /ARGUMENTS A1 THRU A4=
            /NBR OF STEPS FOR MOTORS 1-4
            /ARGUMENTS ARE +OR- INTEGERS OR 0
            /ZERO ARGUMENT LEAVES MOTOR UNAFFECTED
            /A MOTOR CAN BE STOPPED FOR CERTAIN ONLY BY FOPR(5)
            /
            *5200
5200  6314  FDRV,DSCK / DISABLE CLOCK
5201  4543  PUSHF / INITIALIZE
5202  5260  LSTEP1
5203  4544  POPF     / 3 LOCN COUNTERS
5204  5264  LSTEPN
5205  1263  TAD MFOUR
5206  3267  DCA ARGLIM / LIMIT 4 ARGS
5207  4453  LOOP,INTEGR/FLT PT AC TO INTEGER
5210  7450  SNA
5211  1045  TAD FLAC+1
5212  7650  SNA CLA
5213  5223  JMP ZADC
5214  1045  TAD FLAC+1
5215  7710  SPA CLA
5216  5230  JMP MADC
5217  4451  NEGATE/ARG=+, MAKE IT -
5220  1666  TAD I GTIOT
5221  2266  ISZ GTIOT
5222  5232  JMP SETIOT
5223  2266  ZADC,ISZ GTIOT / FLT PT AC=0, IGNORE IT
5224  2266  ISZ GTIOT
5225  2265  ISZ PTIOT
5226  2264  ISZ LSTEPN
5227  5242  JMP ZJMP
5230  2266  MADC,ISZ GTIOT /FLT PT AC=-
5231  1666  TAD I GTIOT
5232  3665  SETIOT,DCA I PTIOT/STORE MOTOR IOT
5233  2266  ISZ GTIOT
5234  2265  ISZ PTIOT
5235  1045  TAD FLAC +1
5236  3664  DCA I LSTEPN
5237  2264  ISZ LSTEPN
5240  1046  TAD FLAC+2
5241  3664  DCA I   LSTEPN/STORE PULSE COUNT
5242  2264  ZJMP,ISZ LSTEPN / DOUBLE PREC INTEGER
5243  2267  ISZ ARGLIM
5244  7410  SKP
5245  5252  JMP MDLY/4TH ARG DONE
5246  4540  PUSHJ/NEXT ARG TO FLT PT AC
5247  1343  ARG
5250  7410  SKP / ARG LIST EXHAUSTED
5251  5207  JMP LOOP
5252  1372  MDLY,TAD MSPEED / SET DELAY B4
5253  3371  DCA MTKT / NEXT MOTOR STEP
5254  3754  DCA I LBRK
5255  6312  CCF / ENABLE CLOCK
```

```
5256  6001  ION
5257  5536  RETURN
            /
5260  5147  LSTEP1,STEP1
5261  5774  LCKTBL,CKTBL
5262  1553  LMIOTB,IOTBL
5263  7774  MFOUR,-4
5264  5147  LSTEPN,STEP1 / THREE
5265  5774  PTIOT,CKTBL      / VARIABLE
5266  1553  GTIOT,IOTBL      / POINTERS
5267  0000  ARGLIM,0
            /
            /CLOCK INTERRUPT SERVICE
            /INTERRUPT RATE 300 HZ
            /GIVEN FIRST PRIORITY
5270  1754  CKSVC,TAD I LBRK/GET SCALER DATA BREAK COUNT
5271  3357  DCA TCK
5272  3754  DCA I LBRK/ZERO THE SCALER
5273  1357  TAD TCK
5274  0101  AND P7700
5275  7640  SZA CLA/TEST FOR HIGH RATE
5276  5347  JMP HIKT
5277  6312  CFLG,CCF/ENABLE CLOCK AND SCALER
5300  1370  TAD RUN
5301  7640  SZA CLA/SOFTWARE SCALER-TIMER RUNNING?
5302  5317  JMP MTRCHK/NO
5303  7100  CLL
5304  1357  TAD TCK
5305  1362  TAD COUNT+2
5306  3362  DCA COUNT+2
5307  7430  SZL
5310  2361  ISZ COUNT+1
5311  7410  SKP
5312  2370  ISZ RUN/SCALER LIMIT REACHED
5313  4756  JMS I LDBLI/INCRT TIME VALUE
5314  5365  TIME+1
5315  7430  SZL
5316  2370  ISZ RUN/TIMER LIMIT REACHED
5317  2371  MTRCHK,ISZ MTKT/MOTOR PULSE DUE?
5320  5755  JMP I LBACK/NO
5321  1372  TAD MSPEED/YES
5322  3371  DCA MTKT
5323  1263  TAD MFOUR
5324  3357  DCA TCK
5325  1373  TAD LM1KT
5326  3335  DCA LMNKT
5327  1374  TAD LM1IOT
5330  3375  DCA LMNIOT
5331  1735  MTLOOP,TAD I LMNKT/MOTOR PULSE LOOP
5332  7650  SNA CLA
5333  5341  JMP NOPLS/NTH MOTOR IDLE
5334  4756  JMS I LDBLI/INCRT MOTOR STEP COUNT
5335  5147  LMNKT,STEP1/VARIES
5336  1775  TAD I LMNIOT
5337  3340  DCA .+1
5340  7000  NOP/MOTOR PULSE IOT
5341  2375  NOPLS,ISZ LMNIOT
5342  2335  ISZ LMNKT
5343  2335  ISZ LMNKT
5344  2357  ISZ TCK/COUNT 4 MOTORS
5345  5331  JMP MTLOOP
5346  5755  JMP I LBACK/ RETURN TO INTRPX
```

```
5347  6352  HIKT,DSSL/CLOSE SOLENOID
5350  3776  DCA I LSOLV
5351  1347  TAD HIKT/RATE EXCEEDS 38 KHZ
5352  3370  DCA RUN/SET FLAG NEGATIVE
5353  5277  JMP CFLG/GO SVC MOTORS
5354  2600  LBRK,BREAK
5355  2606  LBACK,BACK
5356  5157  LDBLI,DBLINC
5357  0000  TCK,0
5360  2000  COUNT,2000 / SOFTWARE SCALER
5361  6000  6000 / SET COUNT HIGH - VALUE AT LOAD TIME
5362  0000  0
5363  0000  0 / 4 WORD
5364  0027  TIME,27/SOFT WARE TIMER
5365  0000  0 / DO NOT CHANGE EXPNT
5366  0000  0
5367  0000  0 / REQD BY 4 WORD
5370  0001  RUN,1/SOFTWARE SC-TM RUN INDICATOR
            /       SET 0 WHEN RUNNING
            /       SET 1 OR 2 WHEN STOPPED
            /       SET LARGE NEG INTEGER (DSSL) FOR XS CT RATE
            /
5371  7777  MTKT,-1 /VARIES
5372  7777  MSPEED,-1 / SET BY FSET-HI SPEED IN EFFECT AT LOAD
5373  5147  LMIKT,STEP1
5374  5774  LMIIOT,CKTBL
5375  5774  LMNIOT,CKTBL/VARIES
5376  5047  LSOLV,SOLVAL
            /
            /
            /
            /       S.P.A.S.T.I.C. - TAPE 8
            /TABLE OF MOTOR IOTS WITH PROPER DIRECTION CHOSEN
            *5774
5774  7000  CKTBL,NOP / MOTOR 1
5775  7000  NOP / MOTOR 2
5776  7000  NOP / MOTOR 3
5777  7000  NOP / MOTOR 4
            /
            /INTERRUPT RESPONSE - REACHED FROM LOCN 2
            *6172
6172  3003  INTRPX,DCA SAVACX/NEW SAVE AC LOCN USED
6173  7010  RAR
6174  5775  JMP I .+1
6175  2603  INTRPT
            /
            /COUNT AND TIME LIMITS
            *6311
6311  0030  COUNTL,30 / COUNT LIMIT SET AT 1000 AT LOAD TIME
6312  7777  7777
6313  7014  7014
6314  0000  0
6315  0027  TIMELM,27 / TIME LIMIT SET AT 4096 SEC AT LOAD TIME
6316  7324  7324
6317  0000  0
6320  0000  0
            /
            *PRNT8-1
7526  5757  JMP I DLIB /LIBRARY EXIT, 4K
            *DLIB
7557  4773  NURCVR /4K POINTER (CLEARS HARDWARE)
```

```
                /THE FOLLOWING STUFF IS FOR 8K ONLY. TERMINATE
                /HERE WITH DOLLAR SIGN FOR 4K.
                /
                /
                /
                /       S.P.A.S.T.I.C. - TAPE 9
                /PATCHES FOR 8K OVERLAY (OMIT FOR 4K)
                FIELD 1
                *LINE0+4
0104  4023      4023 / S
0105  2001      2001 /PA
0106  2324      2324 /ST
0107  1103      1103 /IC
0110  5467      5467 /,7
0111  6640      6640 /6
                *RLIB
0125  4773      NURCVR /NEW EXIT FROM LIBRARY (CLEARS HARDWARE)
                FIELD 0
                *DLIB
7557  0120      DLIB8 /RESTORE AS IN 8K OVERLAY (CHANGED EARLIER THIS PATCH)
                /
                /
                /

ADD     0061            GTIOT   5266            MTLOOP  5331
ABS     1343            HIKT    5347            MTRCHK  5317
ARGINT  4675            ILGL    0634            M27     4746
ARGLIM  5267            INTRPT  2603            MS      0120
BACK    2606            INTRPX  6172            NOFLS   5341
BEGINK  4365            INTSGN  4700            NURCVR  4773
BRANCH  4771            IOTBL   1553            PRNTB   7527
BREAK   2600            LBACK   5355            PTIOT   5265
BUFEND  4675            LBREAK  5022            PT1     0030
CFLG    5277            LBRK    5354            P7600   0104
CHAR    0066            LCKSVC  2654            P7700   0101
CKSVC   5270            LCKTBL  5261            RECOVR  2740
CKTBL   5774            LCOL    5006            RESTRT  5000
COUNT   5360            LCOUNT  5010            RLIB    0125
COUNTL  6311            LDBLI   5356            RNCH    4752
C260    0113            LDIV2   4750            RUN     5370
DBLINC  5157            LINE0   0100            SAVACX  0003
DCFL2   5123            LMIOTB  5262            SAVLK   2601
DIV2    6757            LMNIOT  5375            SCKODE  5102
DLIB    7557            LMNKT   5335            SETIOT  5232
DLIB8   0120            LMSPD   4747            SLIN    4727
ERRORS  2725            LMTIOT  5374            SOLND   5033
EVAL    1613            LMTKT   5373            SOLVAL  5047
EX1     0040            LOCRUN  5104            START   0177
FAND    1142            LOOP    5207            STEP1   5147
FDRV    5200            LRN     4751            STEP2   5151
FLAC    0044            LSOLV   5376            STEP3   5153
FNTABF  0374            LSTEPN  5264            STEP4   5155
FNTABL  2165            LSTEP1  5260            TCK     5357
FOPR    4757            LTIL    5012            TDB1    5174
FSET    4717            LTIME   5014            TIME    5364
FSOL    5023            MADC    5230            TIMELM  6315
FTIM    5105            MCHK    5137            TMKODE  5103
F0      5051            MCOMMA  1353            XFOPR   5112
F1      5050            MDLY    5252            ZADC    5223
F3      5077            MFOUR   5263            ZJMP    5242
F4      5125            MTIN    4740
F5      5117            MSPEED  5372
GS1     1437            MTKT    5371
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